Investment decisions, equivalent risk and bounded rationality

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Abstract.

The Net Present Value maximizing model has a respectable ancestry and is considered by most scholars a theoretically sound decision model. In real-life applications, decision makers use the NPV rule, but apply a subjectively determined hurdle rate, as opposed to the "correct" opportunity cost of capital. According to a heuristics-and-biases-program approach, this implies that the hurdle-rate rule is a biased heuristic. This work shows that the hurdle-rate rule may be interpreted as a fruitful strategy of *bounded rationality*, where several domain-specific and project-specific elements are integrated and condensed into an aspiration level. The paper also addresses the issue of a productive cooperation between bounded and unbounded rationality.

JEL codes: A11, A12, B41, C61, D46, D81, G11, G31, M21.

Keywords. Investment decisions, net present value, hurdle rate, heuristic, bounded rationality, methodology.

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Introduction

This paper deals with the Net Present Value (NPV) methodology, a widely used tool for investment decisions. It is considered theoretically sound and normatively suggested in many corporate finance textbooks (e.g. Copeland & Weston, 1988; Bierman & Smidt, 1992; Rao, 1992; Damodaran, 1999; Copeland, Koller & Murrin, 2000; Brealey & Myers, 2000; Fernández, 2002). The concept of NPV is the brick of a normative building deep-rooted in the maximizing tradition of economics. The NPV methodology may be summarized as follows: suppose a decision maker has the opportunity of investing X_0 in a one-period project generating a payoff X_1. Let i be the project's rate of return and denote with ρ the return rate of the next-best alternative available to the investor; the project should be undertaken if and only if

$$-X_0 + \frac{X_1}{(1+\rho)} > 0\,. \tag{1}$$

The left-hand side of (1) is called the project's *Net Present Value*. The NPV rule says that the decision maker should invest in the project if its NPV is positive. The discount rate ρ is the so-called *opportunity cost of capital*: if a decision maker invests in the project she foregoes the opportunity of earning ρ on her capital X_0. The opportunity cost of capital is then taken as a norm (in the sense of Kahneman & Miller, 1986) and represents the return that the investor *would earn if she invested* in the alternative course of action (see Buchanan, 1969). In general, if one faces two or more mutually exclusive courses of action, one should calculate their NPVs by discounting cash flows at the respective opportunity cost of capital and choose the one with the highest NPV. The NPV model traces back to Fisher (1930), whose analysis is carried out under assumption of certainty, and may be formally derived from the following constrained optimization problem, where the investor must select the optimal consumption plan:

$$\max\ u(c_0, c_1) \qquad \text{subject to} \qquad (m_0 - X_0 - c_0)(1+\rho) + m_1 + X_1 = c_1 \tag{2}$$

where $u(\cdot)$ denotes the investor's utility function, ρ is the market interest rate and c_t, m_t, and X_t are, respectively, the consumption, the income, and the investment flow at time t = 1, 2. Eq. (2) represents the so-called Fisher model. It provides for a separation theorem (optimal investment plan is the same regardless of the optimal consumption bundle) and for a derivation of the net present value rule as in eq. (1) (see McMinn, 2005). Under uncertainty, one cannot say *a priori* that, for example, an *expected* return of 100 is preferable to an *expected* return of 90 if the former is riskier than the latter: one is preferable in terms of return, the other one is preferable in terms of risk (risk-aversion is assumed). So, if alternatives are not equivalent in risk, the NPV rule may not be employed as such, because it only creates a *partial* ordering among alternatives. There is the need of a theoretically correct cost of capital accounting for risk. Among other models, portfolio theory (Markowitz, 1952) and the Capital Asset Pricing Model (CAPM) (Sharpe, 1964; Mossin, 1966) have been developed in corporate finance for explaining the relation between risk and return. The mathematical link between these models and the NPV rule has been provided by several scholars, who proved, since late Sixties, that maximization of shareholders wealth is equivalent to maximization of NPV, where the cost of capital ρ in eq. (1) is the expected rate of return of a traded asset equivalent in risk to the project under consideration (equal systematic risk) and it is computed by making use of the CAPM security market line (e.g.Tuttle & Litzenberger, 1968; Hamada, 1969; Bierman & Hass, 1973; Mossin, 1969; Rubinstein, 1973).

A more recent version of the NPV rule is the "expanded NPV" (Trigeorgis, 1986, Dixit & Pindyck, 1994), which makes use of arbitrage pricing or, alternatively, stochastic dynamic programming. It aims at taking into account possible options intrinsic in the project (option to wait, to abandon, to switch, to temporarily suspend, to enlarge scale, etc.). Proponents of the expanded NPV often call their approach "real options approach", which is but a sophisticated version of the traditional NPV model, where the set of alternatives is inclusive of the options implicit in the project: "one can always redefine NPV by subtracting from the conventional calculation the opportunity cost of exercising the option to invest, and then say that the rule 'invest if NPV is positive' holds once this correction has been made" (Dixit and Pindyck, 1994, p. 7). In other words, while the label 'real options approach' is widespread in the literature, "if others prefer to continue to use 'positive NPV' terminology, that is fine as long as they are careful to include all relevant option values in their definition of NPV" (*ibidem*).[1]

Past and recent empirical evidence shows that actual decision makers turn the NPV model to a rule of thumb: they use a *subjective* discount rate as opposed to a *rational* cost of capital derived from some market model (e.g. CAPM, arbitrage theory, multifactor models). As a result, they employ a criterion generated in the realm of unbounded rationality but give it a distinctive bounded-rationality flavor. This paper aims at showing that this *mixed* rule may prove useful: the bounded/unbounded dichotomy peters out and the hybrid rule discloses a beneficial cooperation between bounded and unbounded rationality.

The paper is organized as follows. Section 1 surveys some empirical evidence on the use of hurdle rates by real-life decision makers so that the NPV rule is interpretable as a bounded-rationality strategy. Section 2 presents evidence that the hurdle-rate NPV rule may furnish close-to-optimal results when compared with the expanded NPV and that it may be viewed as a comprehensive methodology that takes account of several domain-specific and project-specific variables. Section 3 shows that the allegedly sound maximizing NPV have several shortcomings, among which inconsistencies with accepted standards of rationality. Section 4 briefly hints at a normative role of bounded rationality and section 5 presents some

[1] A precursory example of the use of NPV for valuing real options may be found in Merrett & Sykes (1973, p. 129).

evidence indicating that the NPV rule is hardly interpretable as rigorously pertaining to either side of rationality. Some remarks conclude the paper.

1. The hurdle-rate heuristic

There is some awareness in the corporate finance literature that actual decision makers use the NPV rule but do not use the cost of capital suggested by corporate finance textbooks. They employ a subjective *hurdle rate*. Brigham (1975) surveyed 33 large, relatively sophisticated firms. Although 94% of them used DCF methodology, only 61% of the firms using DCF adopted the cost of capital as the discount rate. Summers (1987) surveyed corporations on investment decision criteria finding that 94% of reporting firms use the NPV rule employing a discount rate independent of risk, which is suggestive of the use of hurdle rates. Dixit (1992) recognizes that "firms invest in projects that they expect to yield a return in excess of a required or 'hurdle' rate" (p. 107). "Finance scholars have always been puzzled by the durability of … the hurdle rate rule" (Ross, 1995) and, in actual facts, "we know that hurdle rates ... are used in practice" (McDonald, 2000, p. 30); "it appears common for firms to use investment criteria that do not strictly implement the NPV criterion" (*ibidem*, p. 13), so that their "actions do not reflect the application of current financial theory" (Gitman & Mercurio, 1982, p. 29). Graham and Harvey (2002) surveyed 392 companies, and despite the fact many companies claimed they do employ the NPV technique and use CAPM for estimating the cost of capital, they point out that the use of hurdle rates is predominant. In particular, "small firms are significantly less likely to use the NPV criterion or the capital asset pricing model and its variants" (p. 22). They find that sometimes the use of hurdle rates is explicitly acknowledged: "small firms were inclined to use a cost of equity determined by "what investors tell us to require" [and a] majority (in fact, nearly 60%) of the companies said that they would use a single-company wide discount rate to evaluate a new investment project, even though different projects are likely to have different risk characteristics" (p. 12). Jagannathan and Meier (2002) (henceforth J&M)[2] observe that "managers use a … *hurdle rate*" (p. 3) instead of employing a CAPM-derived cost of capital. Relying on Poterba and Summers' (1995) analysis, they find that "hurdle rates are not … linked to the cost of capital" (p. 22). These findings suggest that actual choice behaviors violate normative NPV and decision makers interpret the rule as a *satisficing* strategy (Simon, 1955), letting the discount rate be a predetermined cutoff level which is considered satisfactory. Let i be the (expected) rate of return of the project, and let k be a hurdle rate subjectively prefixed by the evaluator. A simple heuristic is the following:

undertake the project if $i > k$,

otherwise search for another alternative until the inequality is satisfied.

[2] All following quotations from J&M (2002) refer to the internet version.

It is evident that such a rule may also be rephrased in terms of NPV, with the hurdle rate k as the discount rate: given that $X_1 = X_0(1+i)$, the decision maker will accept an investment with initial outlay X_0 and (expected) final return X_1 if and only if $-X_0 + X_1/(1+k) > 0$. The investment NPV is calculated with the rate k, which represents the minimum rate of return acceptable by the investor. This rule is formally analogous to eq. (2) but is cognitively different. Replacing ρ with k means shifting from the idea of comparing equivalent-risk alternatives to the idea of accepting a satisfactory rate of return. Both ρ and k are cutoff rates, but the former refers to an objectively determined equivalent-risk alternative, the latter refers to a subjectively determined aspiration level. So doing, one leaves the realm of unbounded rationality and reaches the land of bounded rationality. Yet, both rules are expression of an NPV criterion, relying as they are on discounting cash flows at a prefixed discount rate. The investor invests in the project if the value of her payoff function, calculated at the hurdle rate k, is positive; that is, if the rate of return of the project exceeds the aspiration level k. By adopting the hurdle-rate heuristic the evaluator does not confine herself to equivalent-risk alternatives. No alternative course of action is called up, no comparison is accomplished, no maximization is involved. The rate k is not a rate of return of an existing alternative, and therefore it is not an opportunity cost and does not represent a foregone return. It is a subjective threshold that identifies the *personal* minimum required rate of return from the project. The heuristic-minded reasoner is uninterested in knowing whether there exists or not an alternative (either equivalent in risk or not) better than the one under examination, she is just interested in reaching that aspiration level, for subjective reasons.

2. Does the NPV heuristic work?

McDonald (2000) contrasts the hurdle-rate rule with the expanded NPV. The author aims at investigating "whether the use of seemingly arbitrary investment criteria, such as hurdle rates and profitability indexes, can proxy for the use of more sophisticated real options valuation" (p. 13). He wonders whether such "simple rules are relatively robust to changes in project characteristics" and whether "a single hurdle-rate rule [can] yield approximately correct decisions for these projects" (p. 15). Focusing on an option-to-wait decision problem, and implementing variations in the cash-flow growth rate, the project volatility, the discount rate, he shows that

> for a wide range of project characteristics, fixed-hurdle rate and profitability index rule can provide a good approximation to optimal investment timing decisions, in the sense that the *ex ante* loss from following the suboptimal rule is small; it is possible to follow the wrong investment rule without losing much of the *ex ante* value of the investment timing option. In fact, as the investment timing option becomes worth more and it becomes optimal to wait longer to invest, the option value becomes less sensitive to errors in investment rules." (p. 15)

He explains that even though the rise in the discount rate lowers the project value, it also lowers the value at which investment becomes optimal, so that “a decision rule of the form ‘invest when the project has an internal rate of return of 20%’ might in fact be appropriate for a wide variety of projects” (p. 15). He underlines that “*for a variety of parameters*, particular hurdle-rate … rules can provide close-to-optimal investment decisions. Thus, it may be that firms using *seemingly arbitrary* ‘rules of thumb’ are approximating optimal decisions” (p. 13, italics added). J&M (2002) reach the same conclusion holding that the use of hurdle rates should not be deemed less reliable than the use of the opportunity cost of capital as a discount rate: “managers … [take] the right decisions … because they use a hurdle rate that is higher than the cost of capital to capture the option to wait” (p. 12).[3] Although these authors do not recommend the use of aspiration levels and rules of thumb as decisions making criteria[4] it is worth noting that their conclusions implicitly foster the idea that advantages can be taken from undertaking a simple heuristic:

> **[a]** “the advantage of using a hurdle rate is that modelling all possible future options is not necessary” (J&M, 2002, p. 4) and decision makers may “find it useful to use a rule that best justifies making intuitively plausible investment decisions” (McDonald, 2000, p. 26)
>
> **[b]** “managers adjust these rules … when an investment is strategic and expiring.” (McDonald, 2000, p. 30).
>
> **[c]** “use [of a hurdle-rate rule] in practice might stem from the success of apparently arbitrary rules that are revealed over time to be close to optimal. Managers likely observe the capital budgeting practices, in their own and other companies, and in many cases probably mimic what seems to work” (*ibidem*).

It is worth noting that [a], [b] and [c] fit the three premises on which Gigerenzer (2001) bases his notion of adaptive toolbox:

> **[A]** psychological plausibility: models of decision-making should have adequate regard “for the constraints in time, knowledge, and computational capacities that humans face” (Gigerenzer, 2001, p. 38)
>
> **[B]** domain specificity: “each heuristic is specialized for certain classes of problems, which means that most of them are not applicable in a given situation” (Gigerenzer & Todd, 1999, p. 32) and “what works to make quick and accurate inferences in one domain may well not work in another. Thus, different environments can have different … heuristics” (Gigerenzer, Todd & the ABC Research Group, 1999, p. 18)

[3] Some other authors are puzzled by the “intriguing paradox” of such near-optimal choice behaviors: “we have compelling evidence that managers … often do not use real option techniques … On the other hand, strategic decisions under uncertainty appear to conform to some general expectations based on real option theory … The resolution of this paradox would seem to be that, despite their biases, managers’ strategic investment decisions can loosely conform to normative real options models. Managers may employ real option reasoning, without getting all the details correct … Managers’ investment decisions may be ‘directionally correct’, even if they are not completely unbiased” (Miller & Shapira, 2004, p. 281). However, the authors admit that actual choice behaviors take account of variables disregarded by normative models: “normative models for pricing options overlook key aspects of the behavioral and organizational contexts in which investment decisions occur” (p. 282).

[4] “We do not suggest that managers *should* use these rules of thumb” (McDonald, 2000, p. 30).

[C] ecological rationality: this consists in "the match between the structure of a heuristic and the structure of an environment" (Gigerenzer & Selten, 2001a, p. 9). Heuristics are ecologically rational in that "they are adapted to particular environments … [and] can be fast, frugal and accurate by exploiting the structure of information in natural environments" (*ibidem*).

Sentences in [a] exemplify the psychological plausibility [A] of the NPV heuristic (decision makers are not able to take into account all possible future opportunities and outcomes). Sentence [b] reveals that these rules are domain-specific [B] in the sense that when the context changes (strategic investments versus nonstrategic investments, expiring versus nonexpiring projects) the rule is changed or is combined with other rules of thumb (and that the aspiration levels are adjusted too, as suggested by J&M. See above). For example, while the NPV heuristic seems to work well for a variety of industrial projects, the recognition heuristic (Borges et al., 1999; Goldstein & Gigerenzer, 1999, 2002; Borges et al., 2008) is inapplicable in such frameworks. Also, the hurdle-rate rule seems to work least well in case of low volatility, but the errors may be avoided through a combination of rules (e.g. hurdle-rate and profitability index) to give rise to a different heuristic: "This suggests constructing a third rule as a hybrid of the two rules … Such a hybrid rule can prevent the large errors at extreme discount rates generated by either rule alone … this example … demonstrates that firms in practice might find it useful to … consider multiple rules at once" (McDonald, 2000, p. 26). Sentence [c] reveals that the use of the NPV heuristic is ecologically rational [C] due to success over time. McDonald's words also implicitly suggest that the rules of thumb analyzed may be the result of imitation and social learning. In other terms, his words encourage the view that the satisficing NPV rule is a "do-what-others-do" (or "do-what-successful-people-do") strategy (see Laland, 2001. See also Berg and Lien, 2003).

J&M (2002) cite empirical researches showing that managers do not use the CAPM-derived cost of capital, contrary to the normative suggestion of most corporate finance textbooks. Decision makers apply hurdle rates which are usually higher than the cost of capital. The value of waiting to invest is underlined to explain this finding: "using high hurdle rates, companies in fact indirectly account for the existence of timing options" (p. 15). Resting on Poterba and Summers' (1995) data, they show that "a relatively high hurdle rate of 12.2 % is successful in capturing most of the option value as long as the uncertainty of projects' cash flows is high" (J&M, 2002, p. 18) and "If we take into account the option to delay the project, the financial decision is no longer crucially dependent on an exact figure of the discount rate" (p. 19). However, there are other explanations, which suggest that the use of hurdle rates is consistent with established theories in business and finance. For example, a project may absorb managerial skills and thus prevent firm from undertaking other profitable projects in the future. Thus, "If managerial time of a skilful manager is limited, she must decide when it is optimal to take a project. It may pay off to wait and not take the next best positive net present value project" (p. 21), which explains why "the use of a hurdle rate that is higher than the cost of capital … is likely to lead to near optimal decisions" (*ibidem*). This also explains the large variation that Poterba and Summers (1995) find in the hurdle rate of different companies: firms in the same sector face similar systematic risks and, therefore, if they complied with the CAPM-derived discount rate (which is based on systematic risk), they would apply similar discount rates. When managerial resources are in limited supply it is appropriate to use higher discount rates. This view is consistent with the resource-based theory and the literature on Top Management Teams, according to which managerial and firm-specific skills play a pivotal role in value creation (Barney, 1986, 1991, 2001; Grant, 1991; Grant & Robert, 1995; Levinthal, 1995; Bromiley, 2005). Furthermore, if a project is strategic, it may be worth undertaking it even if its NPV (computed with the "correct" cost of capital) is negative, because it promises future opportunities. In this case the use of a discount rate smaller than the cost of capital should be appropriate. Actually, J&M (2002) do affirm that "companies use low hurdle rates for *strategic projects*" (p. 22); "Because it is difficult to estimate the values of all possible upcoming investment opportunities and to assign probabilities how likely these will arise, companies seem to use a low hurdle rate that takes into account that the payoffs in the future are possibly higher than the strategic investment itself suggests" (*ibidem*); "there are strategic situations where making the first move has a commitment value" (Dixit, 1992, p. 119). The view is also consistent with the strategic management literature, according to which strategic decisions are drivers for competitive advantage (Collis & Montgomery, 1995; Quinn & Mintzberg, 1996). For these complex decisions the use of modelling is hardly helpful: "Even if highly simplified and abstracted, the associated SA [strategic assets] decision may not be solvable in closed-form equilibrium … For example, when modelled as a differential game, the problem will probably be not tractable" (Amit & Schoemaker, 1993, p. 40). Agency theory (Jensen & Meckling, 1976; Jensen, 1986) and the costs of external financing may also play a role in determining a hurdle rate different from normative cost of capital. J&M construct a comprehensive NPV function taking account of agency costs and the costs of external financing. The authors claim that this is, according to some recent literature, the right NPV model to be maximized (pp. 23-27). That the costs of external financing may play a major role is also suggested by some empirical research about large reserves of cash retained in the firm (see Mikkelson & Parch, 1999).

Brigham (1975) report that 39% of the respondents change the hurdle rate less than once in a year (p. 20, Exhibit 4), and 32% state that it "depends on conditions": they "revise rates to reflect product and capital market condition, with revisions generally occurring less than once a year" (p. 20). Gitman and Mercurio (1982) report that 50.3% of the companies revise discount rates when environmental conditions change, 13% less frequently than annually, and 11.2% when a major project is evaluated (p. 27). The 'product and market condition' seems to hint at Porter's (1980) analysis, where variables such as rivalry, supplier power, buyer power, threat of substitutes, entry barriers are individuated as fundamental drivers for value creation. As seen above, decision makers raise the hurdle rate to account for the value of waiting, whereas strategic considerations tend to decrease it; changes in project's risk may well imply changes in the threshold, but the notion of *risk* is not necessarily equivalent to a normative one: "Threshold levels will be revalued … In this revising of threshold levels … projects which would have a minor loss if they failed would face a less stringent screening than those that could bankrupt the organization" (Carter, 1971, p. 426). That is, non-ruinous losses versus ruinous losses are given relevance. This concern about risk is "consistent with the bounded-rationality approach of Simon (1957)" (*ibidem*) but has nothing to do with usual capital budgeting textbook prescriptions: "the available models do not capture the essence of risk as defined by decision makers" (Laughhunn, Payne & Crum, 1980, p. 1248).

Overall, these findings evidence that hurdle rates are seen as reference levels that do not change quickly but "that may be gradually adjusted if they become too lax or binding a constraint" (Goodie et al., 1999, p. 351). Historical documents as well reveal that the hurdle-rate rule, frequently used in past centuries, were used as base levels that could be adjusted: "If 15% tended to be the rule of thumb, it was not applied slavishly by the viewers" (Brackenborough, McLean & Oldroyd, 2001, p. 144), who used to change it "depending on the circumstances" (p. 143) (see also Section 5 below). In other words, decision makers condense into a *base* aspiration level several considerations related to uncertainty, decision flexibility, market conditions, future opportunities, limited managerial skills, agency costs, strategic considerations, but the heuristic is exploited in a nonrigid way so that the hurdle rate may change as the above factors change.

3. Problems in the unboundedly rational NPV

The unboundedly rational NPV rule has its own shortcomings. First of all, there is no one NPV, but a proliferation of NPVs differing in terms of risk measure implied, equilibrium model employed, mathematical technique adopted.[5] There is no agreement among scholars on which one is the correct NPV. For example, "academics do not agree on an appropriate equilibrium model even for estimating firm-level discount rates, for which stock returns are observable; estimation of project-level discount rates is even more problematic" (McDonald, 2000, p. 21). Whatever the notion of risk, the equilibrium model, the mathematical technique, many of the assumptions required to implement it are often violated in real life. For example, the use of CAPM-derived cost of capital is often recommended in corporate finance. Resting on a considerable amount of empirical results, J&M (2002) claim that "the CAPM, like all models, is only an abstraction from reality" (p. 5) and "there have been many academic challenges to the validity of the CAPM as applied in practice" (*ibidem*). Lander and Pincher (1998) find numerous disadvantages even in the use of the more sophisticated real-options approach (expanded NPV). They write:

> "Any decision-making framework model is subject to: inappropriate assumptions … poor estimation procedures …failure to incorporate the effects of competition and the strengths and weakness of the firm into all aspects of the investment opportunity, ineffective information gathering of performance and measurement systems, inappropriate emphasis on short-run goals and results, or excessive conservatism or optimism … Many of the required modeling assumptions are

[5] The fuzzy-logic version of the NPV is a further recent addition to the numerous existing versions (Ward, 1989; Chiu & Park, 1994; Abdel-Kader, Dugdale & Taylor, 1998; Buckley, Eslami & Feuring, 2002). Admittedly, the cognitive implications of a cost of capital and a NPV based on fuzzy logic are an open issue.

often and consistently violated in a practical real options application. The necessary additional assumptions required for mathematical tractability limit the scope of applicability." (pp. 542-543)

Furthermore, "The proper treatment of risk is still a major source of concern" (Pinches, 1982, p. 9) and the plethora of risk measures such as "standard deviation, beta, certainty equivalent, risk-adjusted discount rates, conditional probabilities, etc., can be illustrated but not completely agreed upon either in theory or in practice" (Pinches, 1982, p. 11). Among several others, a most stringent assumption frequently used is the completeness of the market. This property makes it possible to construct a replicating portfolio which mimics the project's payoffs. In this case the expected rate of return of the portfolio is taken as the cost of capital and a positive NPV indicates that, regardless of preferences, the investor benefits from undertaking the project and selling short the replicating portfolio. The approach is often called the *options pricing* approach. Barring the fact that short sales are often not allowed, arbitrageurs are nonetheless inevitably exposed to risk of losses (Shleifer & Vishny, 1997), contrary to what textbook arbitrage suggests. Above all, "without spanning, there is no theory for determining the 'correct' value for the discount rate ρ" (Dixit & Pindyck, 1994, p. 152). Smith and Nau (1995) admit that "without a market equivalent for the efficiency uncertainty, we cannot construct a perfect replicating trading strategy or identify a unique risk-neutral probability distribution and thus we cannot determine a unique option-pricing value for the project." (p. 804).[6] They illustrate an example where three strategies are possible and conclude that "the optimal strategy is unclear and all three strategies are potentially optimal" (p. 805). To put it in *eco-logical* terms: the assumptions of the normative NPV model do not fit the environment where decision makers operate. Nor is its success in the environment ever tested: "Finance scholars teach net present value is the right way to evaluate capital investments. We have no research showing firms that use this technique do better than other firms … They believe their theory so much that they do not need to test it" (Bromiley, 2005, p. 70).

The heuristics-and-biases approach is a double-edge weapon. For example, among the various equilibrium models, "the predominant approach to estimating the cost of capital is to use the CAPM" (J&M, 2002, p. 28). The CAPM is massively endorsed in corporate finance (e.g. Copeland & Weston, 1988; Brealey & Myers, 2000; Koller, Goedhart & Wessels, 2005; Damodaran, 2006). "The CAPM provides a framework for estimating the appropriate opportunity cost to be used in evaluating an investment" (Rao, 1992, p. 33). In a classical paper, Rubinstein (1973, footnote 10) proves that, if the CAPM assumptions are met, the project is profitable if and only if

$$\frac{X_1}{X_0} - 1 > r_f + \frac{\lambda \operatorname{cov}\left(\tilde{X}_1, \tilde{r}_m\right)}{X_0}$$

[6] "We also have some semantic problems defining exactly what is meant by the value of a non-traded project" (Smith and Nau, 1995, p. 804, footnote 7).

with r_f =risk-free rate, λ=market price of risk, $\tilde{r}_m$=market rate of return, cov=covariance.[7] The author underlines that the cost of capital is the "appropriate discount rate for the project" (p. 174) and that ''present value risk-adjusted discount rate … forms of this criterion are easily derived" (footnote 8, p. 171) as is shown by a simple manipulation of the above inequation:

$$-X_0 + \frac{X_1}{1 + r_f + \lambda \operatorname{cov}\left(\tilde{X}_1, \tilde{r}_m\right) / X_0} > 0\,.$$

This decision rule boils down "to accepting the project with the highest net present value'' (footnote 14, p. 174). It is worth noting that such a NPV is a *disequilibrium* (cost-based) NPV. Its use is recommended in popular finance textbooks (e.g. Copeland & Weston, 1983, 1988; Weston & Copeland, 1988; Bøssaerts & Odegaard, 2001) and it is so widespread that Ang and Lewellen (1982) consider it "the standard discounting approach" (p. 9) in finance. Magni (2007a) shows that the procedure suggested by Rubinstein violates an accepted standard of rationality: value additivity (warnings against the use of this NPV may also be found in Ang & Lewellen, 1982; Grinblatt & Titman, 1998; Ekern, 2006). In particular, the author shows that the NPV of a portfolio of projects is different from the sum of the NPVs of the projects (Magni, 2007a, Proposition 4.1). This implies that the disequilibrium NPV provides different evaluations (and different decisions) depending on to the way the course of action is depicted. Loosely speaking, to receive a 200€ banknote or to receive two 100€ banknotes is financially equivalent: to employ the disequilibrium NPV means to be trapped in a sort of mental accounting (Thaler, 1985, 1999) because evaluations differ depending on whether outcomes are seen as aggregate or disaggregate quantities. This amounts to saying that the disequilibrium NPV is inconsistent with the principle of description invariance, which prescribes that valuations and decisions must be invariant under changes in description of the same alternative. Violations of this principle are known in the heuristics-and-biases tradition as *framing effects* (Tversky & Kahneman, 1981; Kahneman & Tversky, 1984; Soman, 2004).[8] As opposed to the disequilibrium NPV, some scholars advocate the use of an *equilibrium* NPV (e.g. Bogue & Roll, 1974; Haley & Schall, 1979), which is logically deducted from the CAPM as well. It is often expressed in a certainty-equivalent form:

$$-X_0 + \frac{X_1 - \lambda \operatorname{cov}\left(\tilde{X}_1, \tilde{r}_m\right)}{1 + r_f} > 0\,.$$

This equilibrium NPV is additive, but Dybvig and Ingersoll (1982) and Magni (2007a, 2007c) show that under certain (realistic) assumptions on the market rate of return, this NPV violates the no-arbitrage

[7] Rubinstein's proposal is logically equivalent to other classical proposals presented in the late Sixties and early Seventies by such scholars as Mossin, Hamada, Tuttle and Litzenberger, Bierman and Hass (see Senbet & Thompson, 1978, and Magni, 2007b, for a review).
[8] See also Haley & Schall (1979, pp. 182-183), for unreliability of the disequilibrium NPV in *ranking* projects.

principle.[9] This means that a decision maker complying with the equilibrium NPV is subject to arbitrage losses. Therefore, the equilibrium NPV is not consistent with a tenet which is considered a normative benchmark for economic rationality (Nau & McCardle, 1991; Nau, 1999). As a result, the two CAPM-based NPVs display inconsistencies with accepted standards of rationality. Rigorously speaking, one should say that the CAPM-based NPVs inevitably lead decision makers to infringe accepted standards of rationality; but attention should not be drawn to decision makers: decision makers whose behaviors comply with this model do violate rational benchmarks, but it is not a fault intrinsic in the decision makers' minds, it is a fallacy intrinsic in the very NPV models.

Given that no agreed-upon model exists in the literature, "no general analytic solution to the full-blown financing and investment problem of the firm is currently available. The only recommendation that can be made at present is that management must evaluate all options and *do the best it can*" (Pinches, 1982, p. 12, italics added).

4. Normative role of bounded rationality

The use of hurdle rates in the NPV procedure bears strict analogies with the *tracking-error* strategies of non-maximizers decision-makers, who compare their payoff to various "nonrational" benchmarks. Focusing on a corporate context, Fernández (2002) cites four such benchmarks for shareholders' return: (i) zero (i.e. wealth increase with respect to the beginning of the year), (ii) return on treasury bonds, (iii) shareholders' return of companies in the same industry, (iv) return of the stock market index (pp. 19-20). Others may be used, such as the investors' own last return or average historical return. Berg and Lien (2003), in an expected-utility framework, show that tracking-error decision-makers who, in addition to mean and variance, care about a subjectively-determined benchmark, obtain greater shares of accumulated wealth than pure mean-variance decision-makers. In analogy to this result, in value-based management Young and O'Byrne (2001) explicitly suggest that managers' compensation plans should be based on a historical benchmark such as *increase* of residual income rather *level* of residual income, because an incentive scheme based on excess-profit improvement is more appropriate to align managers' interests to shareholders' interests.[10]

Cognitive illusions themselves may be beneficial: Berg and Lien (2005) show that an overconfidence bias of non-expert decision-makers may shift a standard financial market equilibrium in a Pareto-superior equilibrium, because over-trading leads to improved liquidity and lower transaction costs. Similar results are found by Hirshleifer and Luo (2001), De Long et al. (1991), Kyle and Wang (1997), Dekel (1999), Gintis (2000). Borges et al. (1999) show that ignorance-based investment decisions grounded on the *recognition heuristic* may outperform funds managed by experts. Berg and Gigerenzer (2007) show

[9] Magni (2007c) focuses on CAPM-based capital budgeting and shows that the derivative of the NPV function may be decreasing with respect to the end-of-period cash flow in some state of nature. Dybvig and Ingersoll (1982) focus on asset pricing and show that CAPM does not guarantee absence of arbitrage in a security market.

[10] See Magni, 2009, for an analysis of the notion of residual income.

that it is just a satisficing behavior of the same kind we investigate in this paper that leads regulators to intervene less than they would have to in a world in which all agents were maximizing neoclassical objective functions. Although it remains an open issue to ascertain which violations of standard rationality are beneficial and which are not, more and more evidence is being collected which ought to induce scholars to accept a normative role of behavioral economics and, more in general, of psychology. While a *descriptive* falsification of unbounded rationality models is the accepted role of psychology among the communities of economists and psychologists, a positive role for *normative* justification (corroboration/falsification) of decision-making models and theories may be fruitfully fostered. An explicit stance on this issue is taken by Berg (2003), who endorses the use of behavioral economics as a normative tool. As regards the NPV model, in particular, we have seen that not only the maximizing model leads to violations of accepted standards of rationality (see previous section), but also that a boundedly rational perspective (satisficing) may prove successful. And it is also worth noting that scholars themselves are inclined to support the expanded NPV on the basis of its capability of explaining the deviations of actual behaviors from the normative (traditional) NPV (see section 5). Cosmides and Tooby (1994) complain that "psychologists are called in only to provide second-order corrections to economic theory" (p.327). The growing amount of evidence in the literature of recent times shows that psychology and behavioral economics may be called in to provide first-order corrections as well, to the benefit of economics and, more importantly, of actual decision makers.

5. NPV rule: heuristic or unboundedly rational model?

The classical idea that cognitive processes may be divided into two main classes (Gilovich, Griffin & Kahneman, 2002) is of some concern in cognitive psychology. According to this view, mental processes make use of a heuristic-based system of reasoning and of a rule-based system of reasoning, the former being associative and intuitive, the latter being analytic and reflective. The former employs automatic, effortless, rapid strategies for decision-making, the latter rests on controlled, effortful, deductive processing (Evans, 2004; Sloman, 1996a, 1996b; Sloman, 2002; Kahneman & Frederick, 2002). Each of the two systems has its specific domain, but it is plausible that the two systems are interactive and "function as two experts who are working cooperatively to compute sensible answers." (Sloman, 2002, p. 383). However, one never knows where either system begins and where it ends, and the distinction between the two is rather fuzzy: it is not easy to find clear-cut differences between them (Gigerenzer & Regier, 1996).

This is actually testified by the NPV model we are coping with. The NPV model is presented in the literature as the solution of an optimization problem (e.g. Fisher, 1930, Rubinstein, 1973; Dixit & Pindyck, 1994; McMinn, 2005). Still, there is evidence that it is a *mixed* methodology, a blending of logical and ecological rationality. As may be inferred by several historical surveys, it is the result of rigorous mathematical thinking associated to a more intuitive and adaptive thinking of skillful decision makers. In a period where the quest for axiomatic models was cogent, Fisher (1930) just gave an *optimization* dress to a technique that was practiced long since: since Fibonacci's present-value analysis in 12th century

(Goetzmann, 2005), contributions from mathematicians, philosophers, engineering economists, actuarial scientists nourished and were nourished by the non-optimizing evaluations of properties, trees, lands, collieries, coppices, buildings, leases, shops etc. made by the legal, banking, business communities (Wing, 1965; Edwards & Warman, 1981; Miller & Napier, 1993; Scorgie, 1996; Brackenborough, McLean & Oldroyd, 2001). The use of a systematic discounting procedure adjusted to reflect personal judgment is exemplified in actual evaluations accomplished across centuries: Scorgie (1996) shows that since 13th century "the capitalised value or selling price of arable land and other property was determined by multiplying the annual rental by some *generally accepted* factor" (p. 240, italics added), which is interpretable as a discount factor. A valuation of Lord Cromwell's property in 1469 was obtained by using a factor of 20.[11] The latter only "provided a base valuation" (*ibidem*) and could be changed depending on the case at hand: "The provision for the use of another rate provided some leeway" (Scorgie, 1996, p. 240). Variations were governed by several domain-specific factors, among which "the need to use a higher interest rate where an investment project involved hazards and uncertainty" (p. 242). For example, the risk of flooding for a coal mine (ruinous event) could suggest to decrease the factor from 20 to 4 or to 3 (i.e. raise the discount rate to 25% or 33.33%) (p. 244). Brackenborough, McLean and Oldroyd (2001), focusing on the Tyneside coal industry in the 18th century, report the use of a NPV rule where cash flows "were discounted at interest rates to reflect the viewer's assessment of risk" (p. 141), which means that the "responsibility for assessing the degree of risk was placed firmly in the hand of the client" (p. 144). Quoting directly from original records, the authors confirm that the discount rates reflected "the purchasers' own ideas of the risk and prospects of the concern" and that the decision makers should "judge for himself, and draw his own conclusions" (p. 144). Analysts just provided the formal framework, while leaving investors free to use the rule subjectively "through adjustment of the discount rate" (pp. 150-151). The use of a rigorous procedure combined with personal evaluation is also confirmed by Wing (1965), who analyzes a paper by Van Deventer (1915) where a foreman provides the owner of a small machine shop with what can be seen as an unstated NPV criterion: "First, estimate the probable saving that the investment will make … Second, assign a probable length of life to it … Third, estimate what the investment will cost … Fourth, pick out a minimum rate of return that you will expect" (Wing, 1965, p. 475). That minimum rate of return is a "desired profit rate" (*ibidem*) in a satisficing sense. That the choice of the rate was meant to be subjective is confirmed by the table Van Deventer provides in his paper: it "was supplied with a range of rates of return into which he [the shop owner] could fit his *personal* minimum expected rate" (Wing, 1965, p. 479, italics added). This cooperation is brought into play even in the immaculate unbounded rationality reign, though hardly recognized: when suggesting the use of dynamic programming, Dixit and Pindyck (1994) explicitly leave decision makers free to set their own desired discount rates: "dynamic programming can … be used to maximize the present value of the firm's expected flow of profits, subject to an *arbitrary* discount rate" (p. 149, italics added); "we can … use a dynamic programming approach with an

[11] The implicit discount rate is 5% = (1/20)*100.

exogenously specified discount rate" (p. 185); "The dynamic programming approach started by specifying the discount rate, ρ, exogenously as a part of the objective function" (p. 120). To present a maximization problem where the objective function depends on an arbitrary (thus subjective) hurdle rate means to suggest a blending of an unboundedly rational procedure and a boundedly rational heuristic. Interestingly, the authors themselves are puzzled by their own proposal: "One problem with this investment rule is that it is based on an arbitrary …. discount rate ρ. It is not clear where this discount rate should come from" (p. 147). Yet, their classical book heavily (and commendably) relies on this hybrid NPV rule. Even McDonald (2000), in presenting the maximization procedure, significantly admits: "We will be agnostic about the determination of ρ" (p. 16).

One may even conjecture that the birth of the sophisticated version of the NPV rule (the expanded NPV) has been favored by empirical researches: the latter may have induced scholars to develop a new enhanced NPV capable of explaining the empirical deviations from the traditional NPV rule. This is drawn from their explicit concern about explanation of actual choice behaviors:

> Some recent developments in the theory of investment under uncertainty have offered an interesting new *explanation of these phenomena* … This new approach suggests that textbooks pictures of the dynamics of a competitive industry need … substantial redrawing". (Dixit, 1992, p. 108, italics added)

> The real options literature can *explain* why using a discount rate that is higher than the cost of capital is a good strategy when waiting opens up better opportunities. Such a discount rate is typically referred to as the hurdle rate. (J&M, 2002, p. 13, italics added)

> The option insight also helps *explain* why the actual investment behaviour of firms differs from the received wisdom taught in business schools. Firms invest in projects that are expected to yield a return in excess of a required, "hurdle" rate … such hurdle rates are typically three or four times the cost of capital … firms do not invest until price rises substantially above long-run average cost. On the downside, firms stay in business for lengthy periods while absorbing losses, and price can fall substantially below average variable cost without disinvestment or exit. This also seems to conflict with standard theory, but … it can be *explained* once irreversibility and option value are accounted for. (Dixit and Pindyck, 1994, p. 7, italics added)

> We found qualitative implications, and several approximate quantitative ones, that *conform to experience*—the high hurdle rates used by business firms when they judge investment projects, the relative inefficacy of interest rate cuts as policies to stimulate investment projects, the significant and detrimental effect of policy uncertainty on investment, and so on. (Dixit and Pindyck, 1994, p. 425)

> …there is considerable anecdotal evidence that *firms make investment decisions in a way that is at least roughly consistent with the theory developed in this book* (for example, the use of hurdle rates that are much larger than the opportunity cost of capital as predicted by the CAPM). (Dixit & Pindyck, 1994, p. 296, italics added)

These claims may be interpreted as a regard for providing a theory that should conform to decision makers' actual choices: "note that options advocates justify options models over [traditional] net present value (NPV) models *precisely because* the assumptions of the options models fit the reality better than the assumptions of the [traditional] NPV model" (Bromiley, 2005, p. 69, italics added). Therefore, scholars themselves implicitly (and unawarely) endorse a normative role for psychology and behavioral economics. Thus, if decision makers do not abide by a normative theory, they should not be tagged as irrational. Rather, one could infer that theory exhibits "failures", "anomalies" (Dixit & Pindyck, p. 4), "abstraction from reality (J&M; p. 5), "misleading results" (Bromiley, 2005, p. 69). Decision maker's heuristics may give insights for construction of new theories and models that take account of information, context, environment and personal evaluation. Unbounded rationality alone is not sufficient:

> Any decision-making framework, however, can only improve a manager's understanding of the problem at hand and help him/her to make a more informed and consistent decision. No decision-making framework can guarantee a "good" outcome and *there is no substitute for managerial effort, creativity, experience, knowledge, and critical thinking*…" (Lander & Pinches, 1998, p. 542, italics added).

The "*environmental* indifference that is often assumed by many financial theories and models is not a reasonable assumption for the future" (Crum & Derkinderen, 1981, p. 237, italics added): the quest for a cooperation of bounded and unbounded rationality is compelling.

Concluding remarks

The heuristics-and-biases program draws attention to logical fallacies of human reasoning which cloud human minds (Tversky & Kahneman, 1974; Kahneman, Slovic & Tversky, 1982; Kahneman & Tversky, 1996): choice behaviors are biased because they deviate from accepted standards of rationality. By contrast, advocates of bounded rationality are concerned with showing that heuristics may often prove useful in decision-making (Gigerenzer, Todd & the ABC Research Group, 1999). The latter aver that cognitive illusions disappear once heuristics are seen as adaptive tools rather than logical devices for solving decision-making processes (Gigerenzer, 1996; Gigerenzer, 2000). Gigerenzer and the ABC group endorse the idea that human beings' rationality is ecological rather than logical, and their fast-and-frugal-heuristics program aims at presenting a number of heuristics that are successfully applied in real-life in specific environments. This work deals with the NPV maximization model, which is a keystone in economics and finance. The main results may be summarized as follows:

(1) real-life decision makers often use the NPV criterion, but discount cash flows with a hurdle rate which differs from the cost of capital normatively suggested (e.g. CAPM, arbitrage pricing, multifactor models)

(2) the hurdle-rate rule may be interpreted as a boundedly rational approach to investment decisions: decision makers rest on aspiration levels subjectively determined

(3) some empirical evidence shows that the bounded-rationality approach is ecologically rational, domain-specific, psychological plausible. The hurdle-rate rule leads to close-to-optimal solutions when confronted with the expanded NPV

(4) several factors affect the hurdle rate, among which: decision flexibility, future opportunities, rationing of managerial skills, strategic considerations, agency costs, costs of external financing. Risk is another factor as well, but the notion of risk is not equivalent to the risk measures employed in analytical models

(5) consistency with several theories and models is highlighted, among which real options approach, resource-based theory, Top Management Team literature, agency theory, strategic management literature. The hurdle rate is set at a base level but is not rigidly applied: possible fluctuations around the base level depend on various domain-specific and project-specific factors (such as the drivers just mentioned)

(6) the NPV maximizing model is not univocal: it may take on several different dressings. The use a particular version depends on the circumstances: for example, the arbitrage-pricing NPV may not be used if the actual market is not complete. Some of the versions are often inapplicable and/or reveal inconsistencies with accepted standards of rationality (additivity, no-arbitrage, description invariance)

(7) a normative role for psychology and behavioral economics may prove useful in construction of new theories and revision of older ones on the basis of actual behaviors

(8) an interaction between the two systems of rationality may improve performance. Actually, the very distinction between the two systems of reasoning is rather artificial and only useful as a metaphor (see Gigerenzer & Regier, 1996): as attested by recent historical researches, the origins of the NPV just lie in the common efforts of various categories of people facing the need of both logical and eco-logical rationality.

This paper may suggest a direction for research and hopefully will act as a stimulus for further inquiries. The scientific niche that might be disclosed could offer unexpected views about bounded and unbounded rationality and their interrelations. A possible payoff of such a view is that bounded rationality and unbounded rationality are not necessarily rivals. After all, unbounded rationality itself, as derived from logic and mathematics, may not abstain to consider itself as a derivation of ecological rationality: logic and mathematics should be intended as the most advanced step of human simulation, and simulation is a tool for anticipating; as such, it is indispensable for discovering and creating. The impressive degree we have achieved in such an ability may be seen as the result of an evolutionary process, in which its surviving value has been adaptively tested. Therefore, logic and mathematics, as symbolic tools, assemble the experience of our ancestors (Monod, 1970, pp. 171-172). To put it in a nutshell, even logic is ecological.

More “fluid theories” and more mixed methodologies will help us understand decision makers and help decision makers cope with complex decision problems. With the pleasant by-product of conciliating the two rival parties.

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References

Abdel-Kader, M.G., Dugdale, D. & Taylor, P. (1998). *Investment Decisions in Advanced Manufacturing Technology*. Hants, UK: Ashgate.

Amit, R. & Schoemaker, P.J.H. (1993). Strategic assets and organizational rent. *Strategic Management Journal*, 14(1), 33–46.

Ang, J.A. & Lewellen, W.G. (1982). Risk adjustment in capital investment project evaluations. *Financial Management*, 11(2), 5–14.

Barney, J.B. (1986). Strategic factor markets: expectations, luck, and business. *Management Science*, 32, 1231–1241.

Barney, J.B. (1991). Firm resources and sustained competitive advantage. *Journal of Management.* 17, 99–120.

Barney, J.B. (2001). Is the resource-based ‘view’ a useful perspective for strategic management research? Yes, *Academy of Management Review*, 26(1), 41–57.

Berg, N. (2003). Normative behavioral economics. *Journal of Socio-Economics*, 32, 411–427.

Berg, N. & Gigerenzer, G. (2007). Psychology implies paternalism? Bounded rationality may reduce the rationale to regulate risk-taking. *Social Choice Welfare*, 28, 337–359.

Berg, N. & Lien, D. (2003). Tracking error decision rules and accumulated wealth. *Applied Mathematical Finance*, 10, 91–119.

Berg, N. & Lien, D. (2005). Does society benefit from investor overconfidence in the ability of financial market experts? *Journal of Economic Behavior & Organization*, 58, 95–116.

Bierman, H. & Hass, J. E. (1973). Capital budgeting under uncertainty: a reformulation, *Journal of Finance*, 28, 119–129.

Bierman, H.Jr. & Smidt, S. (1992). *The Capital Budgeting Decision*. MacMillan Company, eighth edition.

Bogue, M.C. & Roll, R. (1974.) Capital budgeting of risky projects with ‘imperfect markets’ for physical capital. *Journal of Finance*, 29, 601–613.

Borges, B., Goldstein, D.G., Ortmann, A. & Gigerenzer, G. (1999). Can Ignorance Beat the Stock Market?. In *Simple Heuristics That Make Us Smart*. See Gigerenzer, Todd & the ABC Research Group (1999).

Borges, B., Goldstein, D.G., Ortmann, A. & Gigerenzer, G. (2008). The Recognition Heuristic: A Fast and Frugal Way to Investment Choice? In C.R. Plott & V.L. Smith (Eds.), *Handbook of experimental economics results*, vol. I. Amsterdam, NL: Elsevier Press/North Holland.

Bøssaerts, P.L. & Odegaard, B.A. (2001). *Lectures on Corporate Finance*. Singapore: World Scientific.

Brackenborough, S., McLean, T. & Oldroyd, D. (2001). The emergence of discounted cash flow analysis in the Tyneside coal industry c.1700–1820. *British Accounting Review,* 33, 137–155.

Brealey, R. & Myers, S.C. (2000). *Principles of Corporate Finance*, McGraw-Hill.

Brigham, E.F. (1975). Hurdle rates for screening capital expenditure proposals. *Financial Management*, 4(3), 17–26.

Bromiley, P. (2005). *The Behavioral Foundations of Strategic Management*. Oxford, UK: Blackwell Publishing.

Buchanan, J. (1969). *Cost and Choice. An Inquiry in Economic Theory*. Chicago: Markham. Republished as Midway reprint. Chicago: University of Chicago Press, 1977.

Buckley J.J., Eslami, E. & Feuring, T. (2002). *Fuzzy Mathematics in Economics and Engineering*. Heidelberg: Physica-Verlag.

Carter, E.E. (1971). The behavioral theory of the firm and top-level corporate decisions, *Administrative Science Quarterly*, 16(4), 413–428, December.

Chiu, C. & Park, C. (1994). Fuzzy cash flow analysis using present worth criterion. *The Engineering Economist*, 39(2), 113–138, Winter.

Collis, D. & Montgomery, C. (1995). Competing on resources: strategy in the 1990's. *Harvard Business Review*, 73(4), 118–128, July/August.

Copeland, T.E., Koller, T., & Murrin, J. (2000). *Valuation: Managing the Value of Companies*, third edition. New York: John Wiley & Sons.

Copeland, T.E. & Weston, J.F. (1983). *Solutions Manual for Financial Theory and Corporate Policy*, second edition. Addison-Wesley Publishing Company.

Copeland, T.E. & Weston, J.F. (1988). *Financial Theory and Corporate Finance*. Addison-Wesley Publishing Company, Inc.

Cosmides, L. & Tooby, J. (1994). Better than rational: Evolutionary psychology and the invisible hand. *The American Economic Review, 84* (2), 327–332.

Crum, R.L. & Derkinderen, F.G.J. (Eds.) (1981). *Capital Budgeting under Conditions of Uncertainty*. Boston: Martinus Nijhoff Publishing

Damodaran, A. (1999). *Applied Corporate Finance: A User's Manual*. New York: Wiley.

Damodaran, A. (2006) *Damodaran on Valuation*, second edition. Hoboken, NJ: John Wiley & Sons.

Dekel, E. (1999). On the evolution of attitudes toward risk in winner-take-all games. *Journal of Economic Theory*, 87, 125–142

De Long, J.B., Shleifer, A., Summers, L.H. & Waldman, R.J. (1991). The survival of noise traders. *Journal of Business*, 64, 1–19.

Dixit, A. (1992). Investment and hysteresis. *Journal of Economic Perspectives*, 6(1), 107–132, Winter.

Dixit, A. & Pindyck, R. (1994). *Investment under Uncertainty*, Princeton NJ: Princeton University Press.

Dybvig P. H. & Ingersoll J. E. (1982). Mean-variance theory in complete markets. *Journal of Business*, 55(2), 233–251.

Edwards, J.R. & Warman, A. (1981). Discounted cash flow and business valuation in a nineteenth century merger: A note. *The Accounting Historians Journal*, 8(2), 37−50.

Ekern, S. (2006). A dozen consistent CAPM-related valuation models – so why use the incorrect one? *Department of Finance and Management Science, Norwegian School of Economics and Business Administration* (NHH). Bergen, Norway. <http://www.nhh.no/for/dp/2006/0606.pdf>.

Evans, J. St. B. T. (2004). History of the dual process theory of reasoning. In K. Manktelow & M. C. Chung, (Eds.), *Psychology of reasoning*. New York, NY: Psychology Press.

Fernández, P. (2002). *Valuation Methods and Shareholders Value Creation*, San Diego: Academic Press.

Fisher, I. (1930). *The Theory of Interest*. New York: The Macmillan Company; (reprinted) Clifton, NJ: Augustum M. Kelley Publishers, 1974.

Gigerenzer, G. (1996). On narrow norms and vague heuristics: A reply to Kahneman and Tversky. *Psychological Review*, *103*, 650–669.

Gigerenzer, G. (2000). *Adaptive Thinking*. *Rationality in the Real World*. Oxford University Press: New York, USA.

Gigerenzer, G. (2001). The Adaptive Toolbox. In *Bounded Rationality*. See Gigerenzer & Selten (2001b).

Gigerenzer, G. & Regier, T. (1996). How do we tell an association from a rule?. *Psychological Bulletin*, 119 (1), 23–26.

Gigerenzer, G. & Selten, R. (2001a). Rethinking Rationality. In *Bounded Rationality*. See Gigerenzer & Selten (2001b).

Gigerenzer, G. & Selten, R. (Eds.) (2001b). *Bounded Rationality. The Adaptive Toolbox.* The MIT Press: Cambridge, Massachusetts, USA

Gigerenzer, G. & Todd, P. M. (1999). Fast and Frugal Heuristics: The Adaptive Toolbox. In *Simple Heuristics That Make Us Smart*. See Gigerenzer, Todd, the ABC Research Group (1999).

Gigerenzer, G., Todd, P.M. & the ABC Research Group (1999). *Simple Heuristics That Make Us Smart*. New York: Oxford University Press.

Gilovich, T., Griffin, D. & Kahneman, D. (Eds.) (2002). *Heuristic and Biases*. *The Psychology of Intuitive Judgment*. Cambridge, UK: Cambridge University Press.

Gintis, H. (2000). *Game Theory Evolving*. Princeton: Princeton University Press.

Gitman, L.J. & Mercurio, V.A. (1982). Cost of capital techniques used by major u.s. firms: Survey and analysis of fortune's 1000. *Financial Management*, 11(4), 21–29.

Goetzmann, W.N. (2005). Fibonacci and the financial revolution. In W.N. Goetzmann & K.G. Rouwenhorst (Eds.), *The Origins of Value*. *The Financial Innovations That Created Modern Capital Markets*, pp. 123–143.

Goldstein, D.G. & Gigerenzer, G. (1999). The Recognition Heuristic: How Ignorance Make Us Smart. In *Fast and Frugal Heuristics That Make Us Smart*. See Gigerenzer, Todd & the ABC Research Group (1999).

Goldstein, D.G. & Gigerenzer, G. (2002). Models of Ecological Rationality: The Recognition Heuristic. *Psychological Review*, 109(1), 75–90.

Goodie A.S., Ortmann, A., Davis, J.N., Bullock, S. & Werner, G.M. (1999). Demons Versus Heuristics in Artificial Intelligence, Behavioral Ecology, and Economics. In *Simple Heuristics That Make Us Smart*. See Gigerenzer, Todd & the ABC Research Group (1999).

Graham, J. & Harvey, C. (2001). The theory and practice of corporate finance: Evidence from the field. *Journal of Financial Economics*, 60, 187–243.

Graham, J. & Harvey, C. (2002). How do CFOs make capital budgeting and capital structure decisions?. *Journal of Applied Corporate Finance*, 15 (1), 8–22.

Grant, R. (1991). The resource-based theory of competitive advantage: implications for strategy formulation. *California Management Review*, 33(3), 114–135.

Grant, R. & Robert, N. (1995). *Contemporary Strategy Analysis: Concept, Techniques, Applications*. Oxford: Blackwell

Grinblatt, M. & Titman, S. (1998). *Financial Markets and Corporate Strategy*. Irwin/McGraw-Hill.

Haley, C.W. & Schall, L.D. (1979). *The Theory of Financial Decisions*, second edition. New York. McGraw-Hill.

Hamada, R.S. (1969). Portfolio analysis, market equilibrium and corporation finance. *Journal of Finance*, 24, 13–31.

Hirshleifer, D., Luo, G.Y. (2001). On the survival of overconfident traders in a competitive securities market. *Journal of Financial Markets*, 4, 73–84.

Jagannathan, R. & Meier, I. (2002). Do we need for Capital Budgeting?. *Financial Management*, 31(4), 55–77. Available at <http://www.nber.org/papers/w8719>.

Jensen, M.C. & Meckling, W.H. (1976). Theory of the firm: managerial behaviour, agency costs and ownership structure. *Journal of Financial Economics*, 3(4), 305–360, Winter.

Jensen, M. (1986). Agency costs of free cash flow, corporate finance, and takeovers. *American Economic Review*, 76(2), 323–329.

Kahneman, D. & Frederick, S. (2002). Representativeness Revisited: Attribute Substitution in Intuitive Judgment. In *Heuristics and Biases*. See Gilovic, Griffin & Kahneman (2002).

Kahneman, D. & Miller, D.T. (1986). Norm Theory: Comparing Reality to Its Alternatives, *Psychological Review,* 93 (2), 136–153.

Kahneman, D., Slovic, P. & Tversky, A. (1982). *Judgment under Uncertainty: Heuristics and Biases*. Cambridge, UK: Cambridge University Press.

Kahneman, D. & Tversky, A. (1984). Choices, values and frames. *American Psychologist*, 39, 341–350.

Kahneman. D. & Tversky, A. (1996). On the reality of cognitive illusions: A reply to Gigerenzer's critique. *Psychological Review*, 103, 582–591.

Koller, T., Goedhart, M. & Wessels, D. (2005). *Valuation: measuring and managing the value of companies*, fourth edition, Hoboken : Wiley & Sons.

Kyle, A.S. & Wang, A. (1997). Speculation duopoly with agreement to disagree: Can overconfidence survive the market test? *Journal of Finance*, 52, 2073–2090.

Laland, K.N. (2001). Imitation, Social Learning, and Preparedness as Mechanisms of Bounded Rationality. In *Bounded Rationality*. See Gigerenzer & Selten (2001b).

Lander, D.M. & Pinches, G.E. (1998). Challenges to the practical implementation of modeling and valuing real options, *The Quarterly Review of Economics and Finance*, 38, Special Issue, 537–567.

Laughhunn, D.J., Payne, J.W. & Crumj, R. (1980). Managerial risk preferences for below-target returns. *Management Science*, 26(12), 1238−1249, December.

Levinthal, D.A. (1995). Strategic management and the exploration of diversity. In C.A. Montgomery (Ed.). *Resource-Based and Evolutionary Theories of the Firm*, pp. 19–42, Boston, MA: Kluwer.

Magni, C.A., (2007a). Correct or incorrect application of CAPM? Correct or incorrect decisions with CAPM?, *European Journal of Operational Research*, 192(2) (January), 549–560,.

Magni, C.A. (2007b). Project selection and equivalent CAPM-based investment criteria, *Applied Financial Economics Letters*, 3, 165−168, May.

Magni, C.A. (2007c). CAPM and capital budgeting: present versus future, equilibrium versus disequilibrium, decision versus valuation. Available at SSRN: http://ssrn.com/abstract=1024716.

Magni, C.A., (2009). Splitting up value: A critical review of residual income theories. *European Journal of Operational Research*. Available online 25 September 2008. DOI:10.1016/j.ejor.2008.09.018.

Markowitz, H.M. (1952). Portfolio selection. *Journal of Finance*, 7(1), 77–91.

McDonald, R.L. (2000). Real options and rules of thumb in capital budgeting, In M.J. Brennan & L. Trigeorgis (Eds.), *Project flexibility, agency and competition: new developments in the theory and application of real options*. New York: Oxford University Press.

McMinn, R.D. (2005). *The Fisher Model and Financial Markets*. Singapore: World Scientific.

Merrett, A.J. & Sykes, A. (1973). *The Finance and Analysis of Capital Projects*, second edition. London: Longman.

Mikkelson, W.H. & Partch, M. (2003). Do persistent large cash reserves lead to poor performance?. *Journal of Financial and Quantitative Analysis*, 38(2), 275-294, June. Available at SSRN: <http://ssrn.com/abstract=186950> or DOI: 10.2139/ssrn.186950.

Miller, P. & Napier, C. (1993). Genealogies of calculation. *Accounting, Organizations and Society*, 18(7/8), 631–647.

Miller, K.D. & Shapira Z. (2004). An empirical test of heuristics and biases affecting real option valuation. *Strategic Management Journal*, 25, 269–284.

Monod, J. (1970). *Le hasard et la nécessité. Essay sur la philosophie naturelle de la biologie moderne*. Paris: Éditions du Seuil.

Mossin, J. (1966). Equilibrium in a capital asset market. *Econometrica*, 34, 768–783.

Mossin, J. (1969). Security pricing and investment criteria in competitive markets. *American Economic Review*, 59, 749–756.

Nau, R. (1999). Arbitrage, incomplete models, and other people's brain. In M. Machina & B. Munier (Eds.), *Beliefs, Interactions, and Preferences in Decision Making*. Kluwer Academic Publishers.

Nau, R.F. and McCardle, K.F. (1991). Arbitrage, rationality, and equilibrium, *Theory and Decision*, 31, 199–240.

Pinches, G.E. (1982). Myopia, capital budgeting and decision making. *Financial Management*, 11(3), 6–19.

Porter, M.E. (1980). *Competitive Strategy*. New York: The Free Press.

Poterba, J.M. & Summers, L.H. (1995). A CEO survey of US companies' time horizons and hurdles rates, *Sloan Management Review*, *37* (1), 43–53.

Quinn, J.B. & Mintzberg, H. (1996). *The Strategy Process: Concepts, Contexts, and Cases*. Englewood Cliffs, Prentice-Hall.

Rao, R. (1992). *Financial Management*, MacMillan Publishing Company.

Ross, S.A. (1995). Uses, abuses, and alternatives to the net-present-value rule. *Financial Management*, 24(3), 96–102.

Rubinstein, M. (1973). A mean–variance synthesis of corporate financial theory. *Journal of Finance*, 28, 167–182.

Scorgie, M.E. (1996). Evolution of the application of present value to valuation of non-monetary resources. *Accounting and Business Research*, 26(3), 237–248.

Senbet, L.W. & Thompson, H.E. (1978). The equivalence of mean–variance capital budgeting models. *Journal of Finance*, 23(29), 395–401.

Sharpe, W.F. (1964). Capital asset prices: a theory of market equilibrium under conditions of risk. *Journal of Finance*, 19(3), 425–442.

Shleifer, A. & Vishny, R.W. (1997). The limits of arbitrage. *Journal of Finance*, 52(1), 35–55, March

Simon, H. (1955). A behavioral model of rational choice. *Quarterly Journal of Economics*, 69, 99–118.

Simon, H. (1956). Rational choice and the structure of the environment. *Psychological Review*, 63, 129–138.

Simon, H. (1957). *Models of Man*. New York: John Wiley.

Smith, J.E. & Nau, R.F. (1995). Valuing risky projects: options pricing theory and decision analysis. *Management Science*, 41(5), 795–816.

Sloman, S. A. (1996a). The empirical case for two systems of reasoning. *Psychological Bulletin*, *119* (1), 3–22.

Sloman, S. A. (1996b). The probative value of simultaneous contradictory belief: Reply to Gigerenzer & Regier (1996). *Psychological Bulletin*, *119* (1), 27–30.

Sloman, S. A. (2002). Two Systems of Reasoning. In *Heuristics and Biases*. See Gilovich, Griffin & Kahneman (2002).

Soman (2004). Framing, loss aversion, and mental accounting. In D.J. Koehler & N. Harvey (Eds.), *Blackwell Handbook of Judgment and Decision Making*, pp. 379–398. Oxford, UK: Blackwell.

Summers, L.H. (1987). Investment Incentives and the Discounting of Depreciation Allowances. In M. Feldstein (Ed.), *The Effects of Taxation on Capital Accumulation*. Chicago: University of Chicago Press.

Thaler, R.H. (1985). Mental accounting and consumer choice. *Marketing Science*, 4(3), 199–214

Thaler, R.H. (1999). Mental accounting matters. *Journal of Behavioral Decision Making*, 12, 183–206.

Trigeorgis, L. (1986). *Valuing Real Investment Opportunities: An Options Approach to Strategic Capital Budgeting*. Doctoral Thesis, Harvard: Harvard University.

Tuttle, D.L. & Litzenberger, R.H. (1968). Leverage, diversification and capital market effects on a risk-adjusted capital budgeting framework, *Journal of Finance*, 23, 427–443.

Tversky, A. & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185, 1124–1131.

Tversky, A. & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, 211, 453–458.

Van Deventer, J. (1915). Jigs and fixtures in the small shop. *American Machinist*, 42(19), 807–809, May.

Ward, T.L. (1989). Fuzzy Discounted Cash Flow Analysis. In G.W. Evans, W. Karwowsky & M.R. Wilhelm (Eds.), *Fuzzy Methodologies for Industrial and Systems Engineering*. Amsterdam: Elsevier.

Weston, J.F. & Copeland, T.E. (1988). *Managerial Finance*, second British edition. London, UK: Cassell Educational Limited.

Wing, G.A. (1965). Capital budgeting, circa 1915. *Journal of Finance*, 20(3), 472–479, September.

Young, S.D. & O'Byrne, S.F. (2001). *EVA and Value-Based Management*. McGraw-Hill.